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China's Environmental and Energy Problems and the Possibility of Japan-China Technical Cooperation

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1 Introduction

In March 2006, China adopted its 11th Five-Year Plan at the National People's Congress. In the Plan, China made a significant shift away from its previous energy policies - which gave top priority to economic progress underpinned by the expansion of energy production - to a policy that focuses on building a resource conservation-oriented and sustainable society[1, 2]. Japan-China energy cooperation has focused on supply, through means such as the development of energy transport infrastructures and resources backed by official development assistance (ODA). As a result of the abovementioned policy change, there is rapidly increasing momentum toward developing a new cooperative relationship in the areas of energy and environmental conservation.

With this backdrop, Japan and China (Japan: Ministry of Economy, Trade and Industry and Japan-China Economic Association, China: National Development and Reform Commission, Ministry of Commerce and Embassy of the People's Republic of China) jointly held the Japan-China Energy Conservation Forum in Tokyo from May 29 to May 31, 2006[3].

This report describes the current status of China's environmental and energy problems, and discusses the possibility of future technical cooperation between Japan and China, taking into account discussions held at the forum.

2 The current status of environmental and energy problems in China and its environmental and energy policies

(1) The current status of environmental and energy problems in China[3]

As China's economic development makes rapid progress, its massive energy consumption is becoming a serious problem. Its total demand for primary energy reached nearly three times that of Japan in 2005. This demand will continue to increase consistently, and China is expected to surpass the United States as the world's largest consumer of oil in 2030. China's electricity demand is currently the second largest in the world, and is expected to continue to increase significantly for the next twenty years at an annual rate of as much as about 140 TWh, equivalent to the annual electricity demand of the whole Kyushu area, the third largest island in the Japanese Archipelago.

Massive consumption of fossil energy has caused serious environmental and energy problems. Li Xinmin, Deputy Director General of the State Environmental Protection Administration, says that energy related issues which occurred in advanced nations over a hundred years have concentrated over a period as short as twenty years in China.

Keenly aware that environmental protection, resource conservation and social harmony are essential to maintaining stable economic growth, the Chinese government has taken various policy measures (Table 1).

(2) Environmental and energy policies in the 11th Five-Year Plan[1-3, 5]

In China's previous energy policies, the top priority was to expand energy production to drive economic growth. However, in its 11th Five-Year Plan published in 2006, China made a significant change aimed at building a resource conservation-oriented society while maintaining a GDP growth rate of 7.5%. Table 2 summarizes the environmental and energy policies in the 11th Five-Year Plan. The Plan set specific numerical goals for building an energy conservation-oriented society, such as an energy consumption intensity reduction of 20%, which were not included in the previous 10th Five-Year Plan.

The priority environmental and energy policies are to

1. give priority to energy conservation;
2. rely on domestic energy supplies, mainly coal;
3. diversify energy sources;
4. optimize the supply-demand structure; and
5. proactively introduce nuclear and renewable energy sources.

The Energy Research Institute of National Development and Reform Commission, a major energy research organization in the Chinese government, has reported that the energy conservation goals set in the 11th Five-Year Plan can be achieved, according to concrete calculations[3]. A reduction in energy consumption equivalent to 195 million tons of standard coal during the period of the 11th Five-Year Plan is required to reduce energy consumption intensity by 20%. It is estimated

Table 1 : Current status of environmental and energy problems in China and policy measures

Issue	Status	Policy measures
Securing energy supply to meet rapidly growing energy demand	• Forecast total primary energy demand : 1,426 million tons of oil equivalent (2003) ⇒ 2,539 M toe (2030) [Reference : Japan - 517 M toe (2002), US - 2,281 M toe (2002)] • Forecast electricity demand : 1,907 TWh (2003) ⇒ 5,573 TWh (2030)	• **Enhancement of the policy-making structure** In May 2005, the National Energy Leading Group was established as the highest-level energy policy decision-making body in China and was led by Premier Wen Jiabao • **Enhancement of energy-conservation policies** 11th Five-Year Plan (2006 to 2010) A numerical reduction goal was set for reducing energy intensity The Renewable Energy Law became effective from January 1, 2006 The law mandates the purchase of renewable energy to cover 10% of total electricity generation in 2010 • **Prioritization of energy technology development** National Medium- and Long-term Plans for Science and Technology Development (2006 to 2020) Science and Technology and Education Development Program (2006 to 2010) National science and technology programs
Increasing imported oil dependency	• Peaking of domestic oil production • Imported oil: 2.4 M BD (2003) ⇒ > 5.23 M BD (2015)	
Surfacing domestic environmental problems	• 95% of coal-fired power plants do not have desulfurization systems ⇒ World's largest producer of sulfur dioxide emissions (25 Mt /y) One-third of land mass suffers from acid rain • Over-mining of coal ⇒ Caved-in land: 400,000ha. Untreated effluent: 3 B m^3 Gaseous waste: 9 to 12 B Nm^3	

Prepared by the STFC based on References[1, 3-5]

Table 2 : Summary of environmental and energy policies in the 11th Five-Year Plan

Viewpoint	Goal	Description (specific numerical goal)
Macro economy	Maintaining stable growth	Doubling the GDP of 2000 by the year 2010 at an annual GDP growth rate of 7.5% Unemployment rate of below 5%, new urban employment of 45 million jobs Three points improvement of the service sector
Energy	Building an energy conservation-oriented society	20% reduction in energy consumption intensity per GDP 30% reduction in water consumption intensity per added industrial value 60% increase in industrial waste recycling rate
Environment	Preventing the spread of pollution	10% reduction in major pollutant emissions 20% increase in forest cover rate Control of GHG emissions

Prepared by the STFC based on References[1, 3-5]

that China as a whole has an energy conservation potential equivalent to 350 million tons of standard coal. However, a significant amount of investment, as much as more than 700 billion yuan, in energy-efficient equipment is required. In light of this and the time required from construction to operation of new installations, it has been questioned whether energy conservation can generate substantial energy savings within the time constraints of the five-year plan.

(3) Science and technology policies[2-4, 6]

National Medium- and Long-term Plans for Science and Technology Development announced by the Chinese government in February 2006 present a vision for energy development as per the "Three-Stage Strategy" shown in Table 3. Energy-related priority research topics and advanced technologies have been selected for the first stage which covers up to 2020, and these are presented in Table 4.

China has developed and implemented strategic priority research and development programs with specific purposes, based on National Medium- and Long-term Plans for Science and Technology Development (Table 5). The areas of energy and the environment had been included as priority research topics in the strategic priority research and development program. The budget for the areas of energy and the environment and its percentage of the total budget has continued to increase since 2000 (Table 6).

Table 3 : Three-Stage Strategy in the National Medium- and Long-term Plans for Science and Technology Development

	First stage	Second stage	Third stage
Year	2006 - 2020	2021 - 2035	2036 - 2050
Description	Build an energy conservation-oriented society through measures such as optimization of industrial structure, enhancement of energy conservation and energy efficiency improvement.	Diversification of energy sources Increase the nuclear share to the current global average of 16%; accelerate the introduction of renewable energy; and introduce hydrogen fuel-cell vehicles.	Achievement of a sustainable energy society Reduce the coal share in primary energy to less than 50%; and increase the combined renewable and nuclear share to more than 30%.

Prepared by the STFC based on Reference [3]

Table 4 : Energy-related priority research topics

Sector	Priority research topic	Description
Energy	Energy conservation in the industrial sector	Development of energy-efficiency technologies for high energy-intensity industries (steel manufacturing, chemical and transport industries); high-efficiency long-life LED lamps; technology for the cascading-use of energy
	Clean-coal technology	High-efficiency coal mining technology; technology to reduce coal pollutants; large gas turbines; integrated gasification combined cycle (IGCC); coal liquefaction technology; coal gasification technology
	Oil and gas exploration technology	Technology for large-scale low-grade oil and gas development; technology to increase the yield of old oil wells; technology to explore and develop deep oil and gas resources
	Renewable energy cost reduction, large scale introduction of renewable energy	Large-scale offshore wind farm technology; low-cost photovoltaic power generation technology; biomass; technology to develop and use geothermal energy
	Very large-scale electric power transmission technology	Large-capacity, long-distance DC power transmission technology; electricity quality monitoring and control technology; high-efficiency power distribution technology; technology to control information on electricity supply
Transport	High-fuel economy vehicles, new energy vehicles	Technology to design and manufacture hybrid, alternative fuel and fuel cell vehicles; high-efficiency, low-emission internal combustion engine technology
Urban development	Energy-efficient buildings	Development and introduction of technology to improve the efficiency of buildings; development of high-insulation building materials; standardization of high-efficiency buildings

Prepared by the STFC based on References [3, 4]

Table 5 : Strategic priority research and development programs

Program	Outline
Key Technologies R&D Program (1982-)	A research program aimed at addressing major science and technology issues closely related to national economic growth, such as energy and transportation
863 Program (1986-)	A program to advance high-technology research aimed at (1) increasing domestic technology levels to those of advanced nations, (2) contributing to economic growth through the industrialization of the results of research, (3) developing infrastructures for high-technology industries, and (4) developing leading personnel who have both strategic ideas and comprehensive interdisciplinary capabilities. The priority areas of research are information technology, biotechnology, new materials, automation technology, energy, laser technology and marine technology. Research topics in the area of energy include nuclear energy, renewable energy, hydrogen energy, fuel cell technology, clean coal technology, and lithium secondary battery technology.
Torch Program (1988-)	This plan aims to industrialize and internationalize the results of high-technology research. 30,000 high-tech corporations are situated in 53 high-tech industry development zones, supplying approximately three million jobs.
973 Program (1997-)	A priority basic research program used for basic research in the university sector; research topics in the area of energy include high-efficiency, clean burning of fossil fuels, coal gasification, liquefaction and alternative energy.

Prepared by the STFC based on References [3, 4, 7]

Table 6 : Year-to-year change in budget for strategic priority research and development programs

Unit: 100 million yuan

Year	Grand total / Energy area total / Environment area total	Percentage	Basic research program*	863 Program	Key Technologies R&D Program	Torch Program
1994	126.58	100.0%	1.23	7.84	14.41	103.10
	12.56	9.9%	0.06	0.89	0.80	10.81
	1.38	1.1%	0.03	0.01	1.34	0.00
1995	195.19	100.0%	1.45	10.24	22.64	160.86
	21.07	10.8%	0.07	1.25	0.41	19.34
	1.86	1.0%	0.04	0.01	1.81	0.00
1996	127.90	100.0%	0.45	1.70	9.98	115.77
	21.89	17.1%	0.03	0.83	0.41	20.62
	0.42	0.3%	0.00	0.00	0.42	0.00
1997	166.54	100.0%	0.52	5.05	16.52	144.45
	10.34	6.2%	0.05	1.10	0.77	8.42
	6.40	3.8%	0.01	0.01	1.58	4.79
1998	207.19	100.0%	1.05	6.39	21.36	178.39
	13.23	6.4%	0.06	1.68	1.06	10.44
	5.65	2.7%	0.04	0.01	0.98	4.62
1999	330.55	100.0%	1.71	10.04	28.87	289.93
	19.68	6.0%	0.10	1.69	2.50	15.40
	8.13	2.5%	0.00	0.05	1.37	6.71
2000	419.43	100.0%	6.88	14.88	35.33	362.35
	26.06	6.2%	1.13	1.21	3.62	20.10
	13.54	3.2%	0.62	0.20	2.12	10.60
2001	No published data available for 2001					
2002	625.57	100.0%	11.01	25.33	125.31	463.92
	43.01	6.9%	1.42	8.97	5.62	27.00
	41.26	6.6%	0.63	1.11	1.69	37.83
2003	788.69	100.0%	10.72	95.04	146.07	536.86
	61.98	7.9%	1.50	14.55	9.96	35.97
	27.23	3.5%	0.70	4.50	5.56	16.47

* Include the Climb Program and the 973 Program

Prepared by the STFC based on Reference[8]

3 Chinese share of science and technology papers and international co-authoring relationships

The Chinese share of science and technology papers was compared with those of the US and Japan to investigate the results of Chinese science and technology policies in the area of energy. Figure 1 compares year-to-year changes in the share of papers in all areas of energy technology as well as in five typical areas for the periods before 1993, from 1994 to 1999 and after 2000.

The Chinese share of papers in all areas of energy was a few percent up to the early 1990s, which was very small compared with Japan and US. This, however, sharply increased in and after the 1990s, being close to Japan and the US. China is still behind the US but is almost comparable to Japan. This indicates that the aforementioned strategic priority research and development program has produced results, and that China is catching up with advanced nations including Japan and the US in terms of output of science and technology. Particularly in the areas of lithium secondary battery and coal gasification technologies, China's share of papers has almost become comparable to those of Japan and the US. In the areas of solar cells, nuclear energy and biomass, China's share has been low still. Until the mid 1990s, the US share of papers in all energy areas was the highest in the world. After the 1990s, Japan sharply increased its share of papers, narrowing the difference with the US and even surpassing it.

The percentage of internationally co-authored papers to all papers in the area of energy published by each country in each year range is shown in Figure 2. This shows the change in international co-authoring relationships. During and before the 1990s, China had the highest percentage of co-authoring relationships with the US in both all and specific areas of energy technology. Since the end of the 1990s, the percentage for the US has been decreasing. In contrast, the percentage of international co-authoring relationships with Japan has been

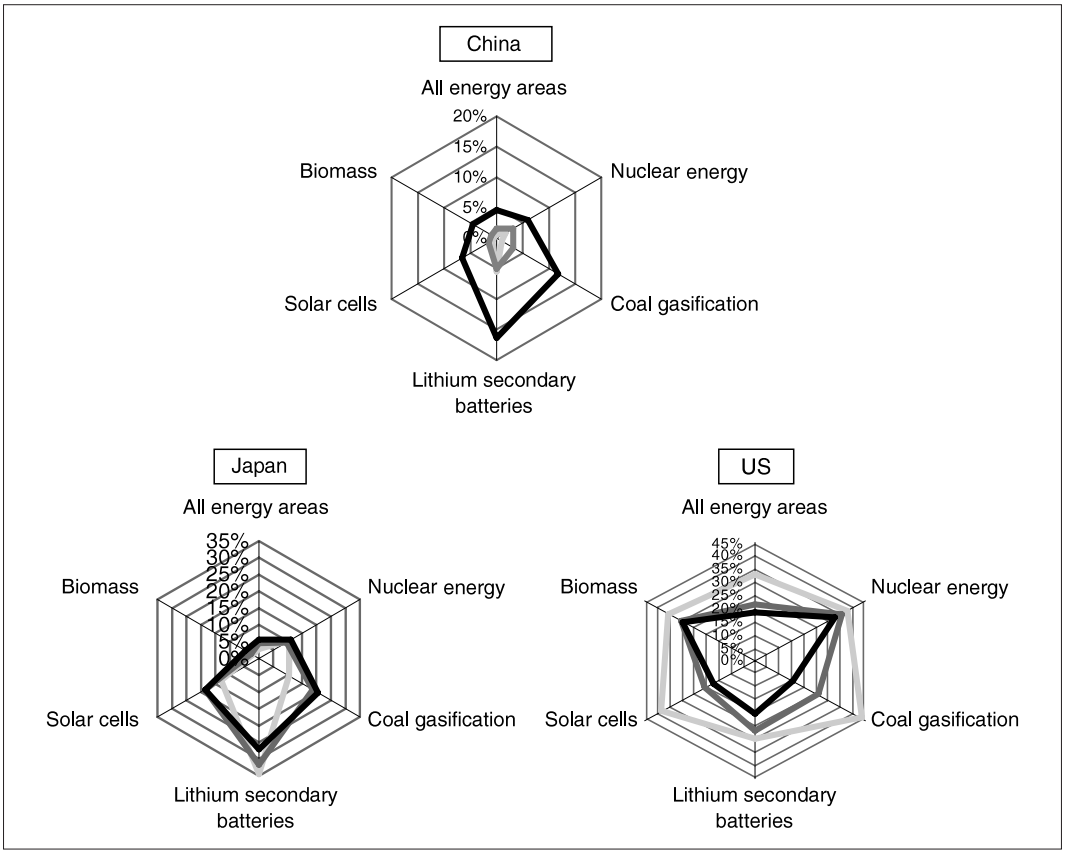

Figure 1 : Change in the share of science and technology papers in the area of energy in China, Japan and US (FY1980-1993, FY1994-1999 and FY2000-2006.06)

Prepared by the STFC based on data from Thomson's Web of Science database

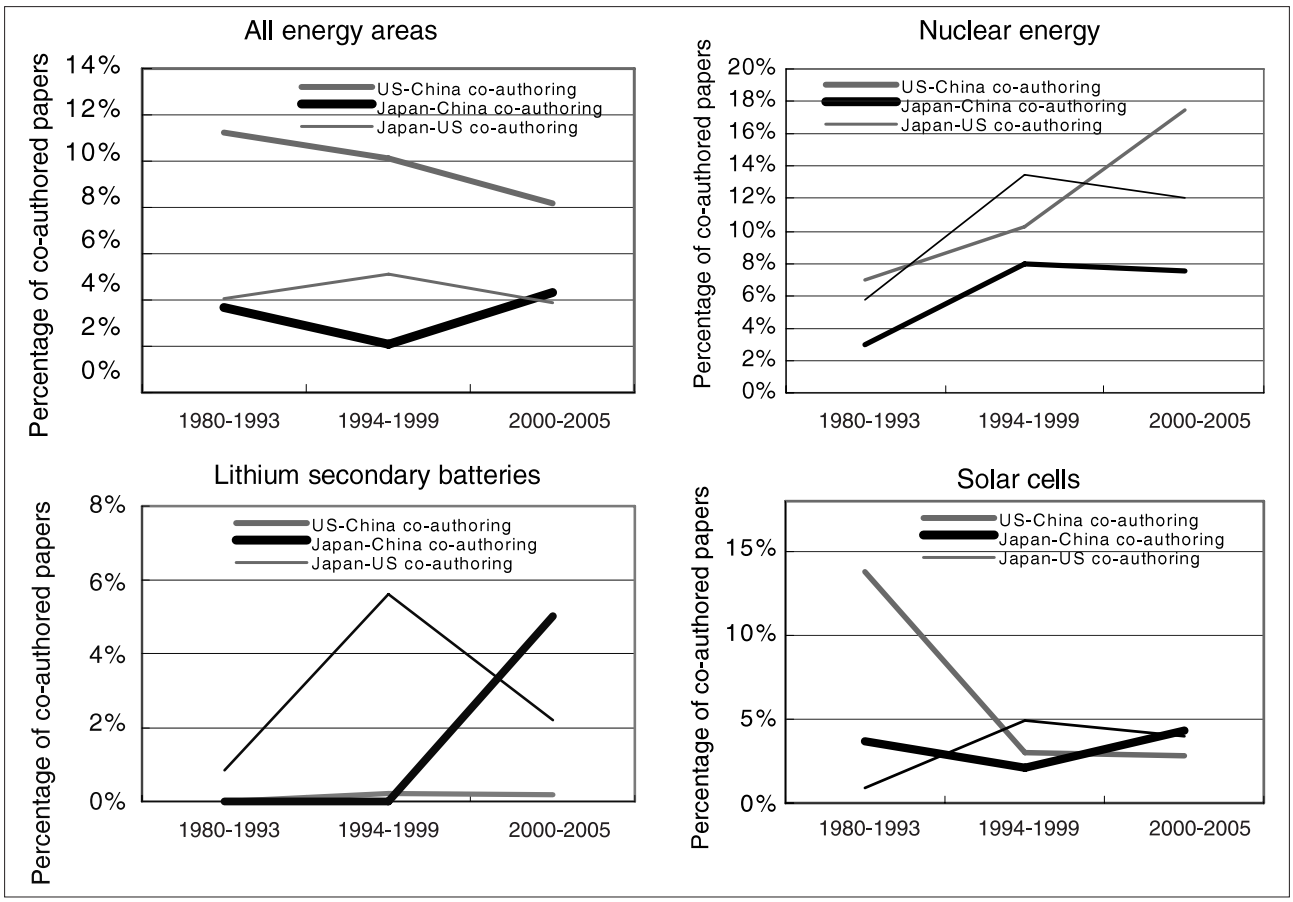

Figure 2 : Change in the percentage of internationally co-authored papers to all papers in the area of energy (FY1980-1993, FY1994-1999 and FY2000-2006.06)

Prepared by the STFC based on data from Thomson's Web of Science database

increasing. China has also become important to Japan as a co-authoring partner in the area of energy. Since the beginning of the 2000s, the Japan-China relationship in co-authoring has exceeded the Japan-US relationship. This trend has been observed in the area of the environment as well[9]. These facts indicate that the Japan-China relationship in basic research and development in the areas of the environment and energy has become closer than with the US. Particularly in the areas of alternative energy and renewable energy technologies, such as lithium secondary batteries and solar cells, the percentage of co-authoring relationships between Japan and China has significantly increased. Shown in Figure 1 are the areas in which Japan has the highest share of papers. In the area of nuclear energy, the US-China relationship is rapidly expanding, and this is the area in which the US has the highest share of papers.

4 Industrialization of basic research in China

The effect of the national high-tech industry development zones created in various locations in China can be seen as many new corporations are growing one after another, utilizing various scientific and technological innovations. About 50% of sales are attributable to new corporations in the areas of electronics and information technology. New corporations in the areas of alternative energy, renewable energy and energy-efficiency technologies, are also doing well, accounting for about 20% of sales (Figure 3). In certain areas, where Japanese technologies such as lithium secondary batteries have been overwhelmingly dominant, there are some Chinese products that are driving out Japanese competition. As previously shown in Figure 1, China has recently sharply increased its share of papers in the area of lithium secondary batteries.

It is characteristic of China that scientific and technological results have led to increased sales by new corporations in the high-tech industry development zones in a short period of time.

It has been pointed out that the innovation system of China, developed independently over the past twenty years, has contributed to the growth of high technology firms[10]. This system focuses on the construction of infrastructures, such as high-tech industry development zones, as well as on human resources, such as those represented by the "Haigui [Sea Turtle] Policy", aimed at promoting the return of high quality researchers from overseas. Due to this system, the results of advanced research at universities have led to the entrepreneuring and the growth of new corporations. It is very likely that the innovation system has become effective for alternative energy, renewable energy and energy-efficiency technologies.

In 2005, the National Energy Leading Group was established as the highest-level energy policy decision-making body in China and was led by Premier Wen Jiabao. This body did not exist previously, and it led to the improvement of administrative organizations. National Medium- and Long-term Plans for Science and Technology Development announced in February 2006, gives priority to establishing an innovation platform for energy science and technology aimed at achieving sustainable economic growth within five years[12]. Recently also in Japan, there has been a vigorous movement to fundamentally reform systems promoting innovation, such as the incorporation of national universities and research organizations. The Chinese case in this area is very compelling.

With the increasing globalization of research and development, governmental and private sectors in Europe have noticed the possibility of establishing a new innovation platform in China, and they continue to promote organizational exchanges with China[10]. For example, the Max Planck Institute of Germany has established the Shanghai Institute for Advanced Studies and Microsoft has developed the Great Wall Plan. It should be expected that Japan and China will develop a long-term knowledge network between the countries.

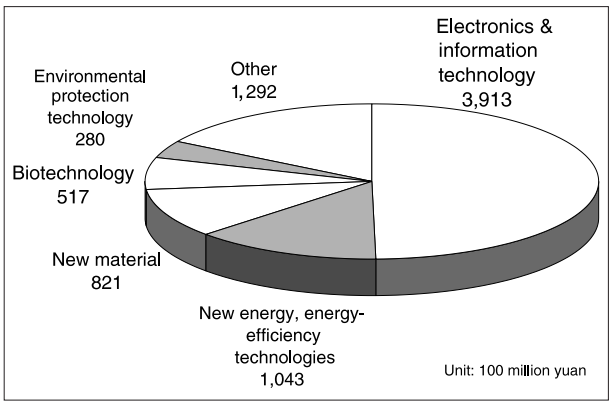

Figure 3 : Sales and product technology areas among corporations in high-tech industry development zones

Prepared by the STFC based on Reference[11]

5 Issues and possibilities of future Japan-China technical cooperation[3]

Given the abovementioned environmental and energy problems facing China, the Japan-China Energy Conservation Forum mentioned in Chapter 1 was held. About 850 concerned parties (China: approximately 200 people, Japan: approximately 500 corporations), including cabinet members, participated in the forum and exchanged opinions on a wide variety of issues including programs, policies, technologies and experiences concerning energy conservation and the environment. The participants actively discussed how future Japan-China technical cooperation should be developed. Table 7 summarizes, based on the keynote speeches, Japan's and China's recognition of the technical cooperation on energy conservation and environmental issues. Japan and China confirmed that the purpose of Japan-China technical cooperation is to help solve China's environmental and energy problems as well as to contribute to the sustainable economic growth of China and stabilization of the Asian region, leveraging the experience and technology of Japan, which has survived two global oil shocks. Both countries generally agreed on the content and areas of technical cooperation. Some concrete projects were also agreed upon in the forum (Table 8).

The Japanese government has commented that the promotion of corporate self-management and information disclosure to consumers are the keys

Table 7 : Various viewpoints for Japan-China technical cooperation

	Japanese viewpoints	Chinese viewpoints
Purpose	Solving China's environmental problems leveraging Japan's experience and technologies Operation of environment-related and energy conservation businesses by Japanese corporations in China	Providing attractive markets for Japanese corporations Contributing to the stabilization of East Asia through China's sustained and mutually complementary economic growth Enhancing the relationship between Japan, as a country implementing CDM projects, and China, as a country receiving such projects
Points of success	Building a cooperative relationship through businesses in the private sector Developing laws concerning producer responsibility and disclosure that helps consumers make judgments in China Prior preventive action Promoting corporate self-management; Corporate motivation for investment in energy-efficient equipment with cost awareness and subsidy programs	Developing a win-win relationship by promoting cooperation in business Establishing a mechanism for communication between the two countries (inter-government policy studies, platform for inter-corporate exchange)
Content	Designing programs for technology transfer, cooperation in human resource development, environmental regulation and accelerated energy conservation	Provision of technological capabilities, funding capabilities and know-how (stockpiling of imported resources, operation of environmental equipment), development of energy-efficiency technologies
Technical area	Clean coal technology, renewable energy technology, and solutions for yellow sand and acid rain problems	Afforestation, effluent treatment, clean production technology, prevention and monitoring of automobile exhaust emissions, clean fuels (alternative fuels), energy-efficient buildings
Proposed effective activity	(1) Providing model cases with support in the form of funds and tax incentives (2) Developing post-yen loan schemes (3) Holding technical meetings on energy conservation and environmental protection (4) Personnel exchange	(1) Establishing a model research laboratory, (2) holding technology shows and exchange meetings, (3) promoting inter-corporate joint research and business projects, (4) holding the Japan-China Energy Conservation Forum on a regular basis
Pending issues	Improving business conditions in China Protection of investors' benefits (investment agreements, protection of intellectual property rights)	Stabile political relationship between China and Japan Improving a sense of responsibility and ethics among Chinese corporations, increasing public awareness, non-disclosure of core technologies by Japanese corporations

Prepared by the STFC based on Reference[3] and comments and opinions from the forum

Table 8 : Concrete projects agreed upon in the Japan-China Forum on Energy Conservation and the Environment[14]

Implementing body	Content and name of agreement	Description
Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (Japan) National Development and Reform Commission (China)	Implementation of inter-governmental communication concerning energy-conservation policies	Developing schemes to promote energy conservation and a framework for inter-governmental communication aimed at promoting the exchange of opinions on policy issues
Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (Japan) National Development and Reform Commission (China)	Cooperation in human resource development in the area of energy conservation	Providing training in Japan to help develop human resources for developing and operating energy conservation schemes in China (a few hundred trainees over five years)
Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (Japan) Department of International Cooperation, State Administration of Work Safety (China)	Training programs in the areas of coal production and coal mining safety	Continuing the training of Chinese engineers in the areas of coal production and coal mining safety beyond 2007
Yazaki Corporation (Japan) TEDA Investment Co. (China)	Establishment of a joint venture "Tianjin Binhai Energy & Development Co., Ltd."	Establishing joint ventures providing energy-conservation diagnosis services, technical services and management consultation services
International Center for Environmental Technology Transfer (Japan) Tianjin Economic-Technological Development Area Administrative Commission (China)	Consignment agreement between the International Center for Environmental Technology Transfer (ICETT) and the Tianjin Economic-Technological Development Area Administrative Commission	Conducting surveys and research on the Tianjin Economic-Technological Development Area; providing training on effluent treatment technology and seminars on environmental technologies
Hitachi Appliances, Inc. (Japan) Shenzhen Coolead Industry Co., Ltd.(China)	Product purchase agreement	Installing 8,400 air-conditioning systems for energy-efficient buildings

to success in solving environmental and energy problems. However, the Chinese government has pointed out that currently there are impediments typical of the period of transition to a market economy, such as problems in improving a sense of responsibility and ethics among Chinese corporations and increasing public awareness.

Both countries have agreed on the importance of building a cooperative relationship based on the private-sector. The Chinese participants have pointed out that when transferring technologies, Japanese corporations excessively disclose their core technologies and thus that a constructive cooperative relationship has not been developed. On the other hand, the Japanese participants have expressed concern over the protection of investors and intellectual property rights, and thus differences in views have been identified. These issues cannot be avoided in establishing cooperation focusing on industrial technologies in the private sector.

As explained in Chapter 3, cooperation between Japan and China is already extensive in basic research and development in the areas of environment and energy. However, there is still much room for cooperation between the two countries in solving common problems. Japan and China have essentially agreed on the priority of research topics concerning science and technology policies in the areas of environment and energy. At the Japan-China Energy Conservation Forum, discussions focused on the cooperative relationship in the area of industrial technology. Participants from China proposed establishing a model research laboratory and conducting inter-governmental policy studies. Therefore, strategic concurrent discussions in the areas of basic research and development and innovation will give a more concrete form to the desired complementary relationship between the two countries and will help to build a smoothly functioning cooperative relationship.

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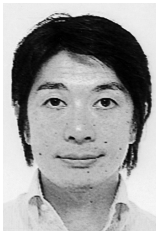

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